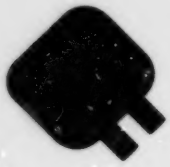
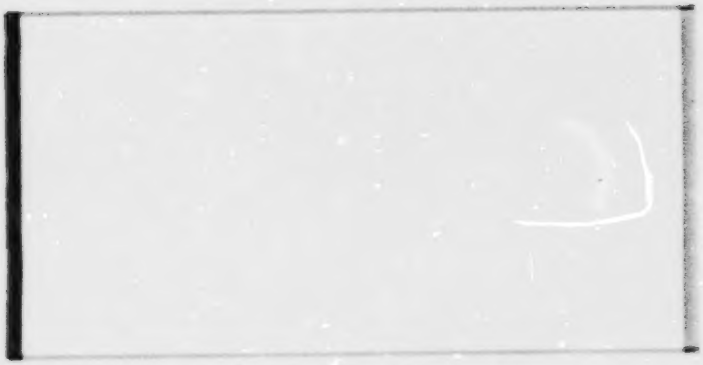


Ontario Hydro



91602
nsw 82-10

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if Reproduced in Whole or in Part.

ontario hydro
research division

LABORATORY STUDIES OF FISH CAPTURE EFFICIENCY OF CONE-SHAPED INTAKE STRUCTURES

Report No 84-207-K

David W. Rodgers
Biologist
Biological Research Section
Chemical Research Department

ABSTRACT

Laboratory studies were conducted to determine criteria which enhance the capture of fish by the intake current of a fish return system such as that proposed for Darlington NGS. With mercury vapor lighting, the efficiency of capture of gizzard shad was higher for cone-shaped intake structures with longer arcs, in which current velocity increased more gradually. Without mercury vapor lighting, no consistent pattern was apparent between capture efficiency and arc length. Capture efficiency of yellow perch appeared to increase at higher current velocities, however, the large variability among replicate samples limited tests of statistical significance.

job	file	date	report no.
740634-105-492	837.315	July 10, 1984	84-207-K

TABLE OF CONTENTS

	Page
INTRODUCTION	1
MATERIALS AND METHODS	1
RESULTS	6
DISCUSSION	8
SUMMARY	10
ACKNOWLEDGEMENTS	10
REFERENCES	11
APPENDICES	12
DISTRIBUTION	last page

LIST OF FIGURES

		Page
Figure 1	Fish Capture Intake Model.	3

LIST OF TABLES

Table 1	Summary of Test Conditions	5
Table 2	Effects of Filtered Mercury Vapor Lighting and Current Velocity on Capture Efficiency of Yellow Perch.	6
Table 3	Effects of Filtered Mercury Vapor Lighting and Intake Structure on Entry and Capture of Gizzard Shad.	7
Table 4	Effects of Filtered Mercury Vapor Lighting and Diurnal Cycle on Capture Efficiency of Gizzard Shad With No Intake Structure (Recessed Intake).	8

LIST OF APPENDICES

APPENDIX 1	Current Distribution for 2, 3 and 4 m Arcs	12
APPENDIX 2	Number of Yellow Perch Captured in Individual Trials	16
APPENDIX 3	Number of Gizzard Shad Captured in Individual Trials.	17

91601
new 82-10

ontario hydro
research division

To Dr. W.R. Effer
Manager
Environmental Studies
and Assessments

LABORATORY STUDIES OF FISH CAPTURE EFFICIENCY OF CONE-SHAPED INTAKE STRUCTURES

INTRODUCTION

An effective fish return system requires an efficient means of attracting and concentrating fish and a mechanism for transporting fish back to their original waters without appreciable mortality or injury. Laboratory studies in 1981 demonstrated that the Hidrostal pump was effective in transporting representative Great Lakes fish with little mortality or apparent injury (OHRDR 82-295-K). Further studies in 1982 demonstrated that mercury vapor lighting significantly improved the efficiency with which a Hidrostal pump captured fish (OHRDR 83-142-K; OHRDR C83-54-K). The present studies investigated the susceptibility to capture of fish attracted to a field of rapidly increasing current velocity. These tests were conducted to develop criteria for the design of the intake channel of a fish return system which has been proposed for Darlington NGS. This research was conducted at the request of Environmental Studies and Assessments as part of the 1983 Capitalized Once Through Cooling Program.

MATERIALS AND METHODS

Juvenile perch, Perca flavescens, and gizzard shad, Dorosoma cepedianum, (10-20 cm total length) were collected from local waters using seine and dip nets respectively. Fish were transported to the laboratory in oxygenated containers and maintained in aerated holding tanks (approximately 10,000 L) supplied with dechlorinated Toronto water. Water temperatures were 15-20 deg C during tests with perch and decreased from 13 to 7 deg C during tests with gizzard shad. Fish were fed to satiation with artificial diets of either cat food (perch) or a

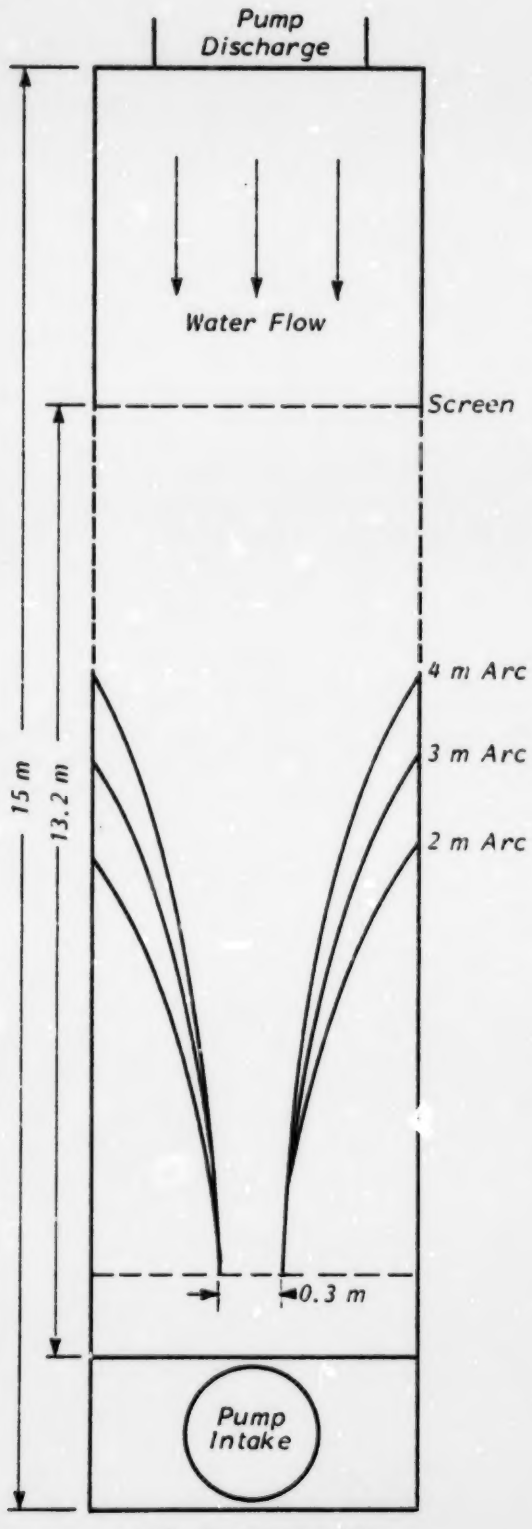
mixture of Tetramin and oatmeal (gizzard shad) three times weekly. Photoperiod was maintained at approximately 10 h of light and 14 h of dark for all tests.

Tests were conducted in a long narrow tank (15 x 1.2 m) with clear acrylic side walls supplied with dechlorinated Toronto water and maintained at a depth of approximately 1 m. A large capacity (75 hp) pump circulated water throughout the tank. Water from the recessed pump return intake at one end of the tank passed through an external conduit to the pump. The water from the pump was discharged at the opposite end of the test pool (Figure 1) and then passed through a baffle screen before entering the fish testing area. The test area extended from this upstream baffle to the intake structure with the fish holding area extending for approximately 3 m from the upstream baffle to a removable mesh screen (1 cm square mesh) midway down the tank. The intake structures were located at the downstream end of the tank. When the tapered, cone-shaped structures were used, their apex was located approximately 0.5 m from the screened pump return intake which was recessed into the floor of the test tank. The space behind the intake structure provided a refuge for fish which had passed through the intake. In tests without an intake arc, the recessed intake well served as the intake structure. In these later tests, the screen flush with the bottom of the return intake was moved further into the return well and captured fish were retained in this well.

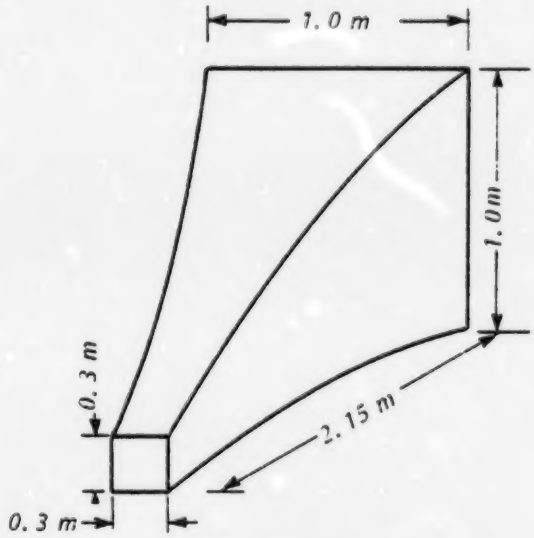
The side walls of the cone-shaped intake structures could be adjusted to form arcs of 2, 3 or 4 m radius (Figure 1). The side walls were covered by a flat sheet of clear acrylic plastic and tapered to a 0.3 x 0.3 m opening. A mercury vapor lamp (250 w clear mercury vapor bulb) fitted with blue plastic filters was suspended over the intake. In initial tests, the lamp was mounted directly over the mouth of the cone and projected downwards. In later tests, the lamp was placed near the apex and projected towards the mouth of the cone.

The test tank was surrounded by curtains (floor to ceiling) to isolate it from other activities in the laboratory. In tests with gizzard shad, the clear acrylic flume was covered with black plastic as initial observations indicated that fish may have orientated to the dark lines cast by the tank support structure.

The flow of water from the pump was controlled by a series of valves. The majority of tests were conducted with the valves completely open and water maintained at a depth of approximately 1 m which produced uniform current velocities of approximately 25-30 cm/s within the main body of the test tank. (All current velocities were measured with a Marsh McBirney - Model 20 Water



(b) Overhead View



(b) Cone Profile

FIGURE 1
FISH CAPTURE INTAKE MODEL

164683 RD

Current Meter). Current velocities increased within the cone-shaped intake structures, reaching velocities of greater than 250 cm/s at the apex of the intake structure. These velocities were selected to approximate current velocities expected with the proposed fish return system for Darlington NGS (A. Christie - personal communication). The current velocities at the mouth of the structure were similar between cone-shaped intake structures. However, the rate of increase in current velocity, varied among the arcs used, particularly towards the rear of the structure with the most rapid rate of increase observed with the shortest arc (2 m). (Profiles of the currents obtained with each arc are given in Appendix 1.) A limited series of tests with perch were conducted with the valves partially closed. With the valves partially closed, current velocities within the test tank were reduced to 10-15 cm/s and currents at the apex of the intake structure were reduced to 150 cm/s. In tests without an intake arc, horizontal current velocities were approximately 20 cm/s throughout the tank. Within 10 cm above this submerged intake, vertical current velocities were approximately 60 cm/s but dropped to less than 20 cm/s at 30 cm from the intake and beyond.

The filtered mercury vapor lamp produced light which was concentrated in the blue to violet (420-520 nm) range of the visible spectrum (OHRDR 78-516-K). Light in this range of the spectrum appears to be effective in attracting and concentrating fish (OHRDR 82-288-K; OHRDR 83-142-K). When the lamp was mounted at the rear of the intake cone, light intensities were 30-40 lux at the apex of the intake, 5-10 lux at the mouth of the intake, 2-5 lux at 1 m from the mouth of the intake and 1-2 lux beyond this distance. (Light intensity was measured with a Radiometer, Model L1-185A photometer). When the lamp was suspended over the mouth of the intake structure, light intensities were 15-20 lux at the mouth of the structure, then decreased to approximately 10 lux at 0.5 m from the mouth of the intake, 5 lux at 1 m and 1-2 lux at 2 m and beyond.

For each test 25 fish were transferred to the fish holding area of the test tank and the pump started. The mercury vapor light, if used, was turned on at the same time. Fish were restricted to the holding area for the first hour of the test, after which the screen at the rear of the holding area was removed, permitting the fish to approach the intake. The test was continued for the next hour and the number of fish passing through the intake structure recorded. In later tests, the number of fish entering the intake structure but not passing through it was also recorded. The test was stopped after one hour, fish removed from the test pool and new fish added for subsequent tests. Normally three tests were conducted each day with mercury vapor lighting used on alternate tests. The temperature of water in the test

tank was initially the same as the holding tank but would increase by 3-5 deg C as the day's tests progressed. However, increases in temperature of this magnitude should not affect the sustained swimming performance of the test fish (Otto and O'Hara Rice 1974; OHRDR 79-362-K).

As the objective of these tests was to develop the most effective fish capture system, apparently unsuccessful tests were not replicated for all possible experimental configurations (Table 1). Perch were tested using the 3 m arc with the lamp mounted

TABLE 1

Summary of Test Conditions

Intake	Species	Test Conditions
No Arc	shad	Mercury Vapor Light (+/-) Day/Night Tests
2 m Arc	shad	Mercury Vapor Light (+/-)
3 m Arc	shad/perch	Mercury Vapor Light (+/-) Full/Reduced Velocity (perch)
4 m Arc	shad	Mercury Vapor Light (+/-)

over the mouth of the intake structure while experimental variables were mercury vapor lighting (presence or absence) and test speed (full or half velocity). With shad, the effects of mercury vapor lighting and intake structure design were tested. In addition, the lamp was mounted at the rear (apex) of the intake structure, which produced a gradient in light intensity, with highest light intensities located in region of fastest current. With no intake structure, tests were conducted at night (17:00 - 24:00) and during the day (08:00 - 15:00) to determine the effects of diurnal activity patterns on capture efficiency.

Results of experiments were analyzed using appropriate analysis of variance models. On the basis of an examination of residual and normal probability plots, data appeared to comply with the assumptions of normality and equivalence of variance required for

these statistical tests. Appropriate cell means were compared using the least significant difference method if the F-ratio was significant ($P<0.05$). In all statistical tests of significance, differences between cell means were considered significant if $P<0.05$. Data for individual trials are summarized in Appendices 2 and 3.

RESULTS

The average capture efficiency of yellow perch at maximum test velocity (with the valves full open) was approximately double that obtained at a reduced test velocity (with the valves partially closed - Table 2). However, because of the high

TABLE 2

Effects of filtered mercury vapor lighting and current velocity (valve position) on capture efficiency (%) of yellow perch (Mean+SE, 25 fish/trial, number of trials in parentheses).

	Light on	Light off
Maximum current velocity	40+27 (3)	44+18 (3)
Reduced current velocity	20+20 (4)	16+5 (3)

variability among replicate samples the difference between these current velocities was not statistically significant. Filtered mercury vapor lighting did not significantly affect capture efficiency of perch.

The efficiency of capture of gizzard shad by the different intake structures differed between tests conducted with and without filtered mercury vapor lighting. Accordingly, these patterns are examined separately for each lighting condition. With filtered mercury vapor lighting, capture efficiency increased regularly with arc length of intake structure, from 6% with no intake structure to 58% with the 4 m arc (Table 3). Mean capture

TABLE 3

Effects of filtered mercury vapor lighting and intake structure on entry and capture efficiency (%) of gizzard shad (Mean+SE, 25 fish/trial, number of trials in parentheses).

	Light on		Light Off	
	Entry(#)	Capture(%)	Entry(#)	Capture(%)
No arc	-------	6+3 (4)	-------	28+9 (4)
2 m arc	25+6 (4)	33+17 (4)	13+6 (4)	10+5 (4)
3 m arc	21+4 (4)	47+11 (4)	37+4 (4)	68+11 (4)
4 m arc	48+6 (4)	58+8 (4)	21+4 (2)	22+8 (2)

efficiencies of the 2, 3 and 4 m intake structures were significantly greater than that obtained without an intake arc. Among intake structures, mean capture efficiency of the 4 m arc was significantly greater than that of the 2m arc, however, mean capture efficiency of the 3 m arc was intermediate between these extremes and not significantly different from either 2 or 4 m arcs. Without filtered mercury vapor lighting, the pattern of change in capture efficiency with intake structue was less consistent (Table 3). In this case, mean capture efficiency of the 3 m arc was significantly greater than that of no arc and the 2 and 4 m arcs which did not differ significantly. Although mercury vapor lighting did not consistently affect capture efficiency, efficiency of the 4 m arc was significantly greater when mercury vapor lighting was employed. Without an intake arc, capture efficiencies of the recessed intake were low under all conditions and were not significantly influenced by mercury vapor lighting or time of day (Table 4).

TABLE 4

Effects of filtered mercury vapor lighting and diurnal cycle on capture efficiency (%) of gizzard shad with no intake structure (recessed intake) (Mean+SE, 25 fish/trial, number of trials in parentheses).

	Light on	Light off
Day	6+3 (4)	28+9 (4)
Night	18+10 (4)	24+11 (4)

The trends observed in numbers of fish entering the intake structures generally paralleled those of fish capture (Table 3). Again the pattern of change in numbers of fish entering the intake structures differed between tests conducted with and without mercury vapor lighting and each condition must be examined separately. When mercury vapor lighting was used, a significantly greater number of fish entered the 4 m arc than the 2 or 3 m arcs which were not significantly different from each other. Without mercury vapor lighting, significantly greater numbers of fish entered the 3 m arc than the 2 or 4 m arcs which did not differ significantly. For the 4 m arc, a significantly greater number of fish entered the structure when the mercury vapor lights were employed. However, this pattern was reversed with the 3 m arc, while mercury vapor lighting did not significantly affect the numbers of fish entering the 2 m arc.

Both perch and gizzard shad were generally observed to swim with their head orientated into the current (ie fish were positively rheotactic). However, shad were observed to swim up and down the test tank while perch generally maintained position at the upstream end of the test tank. Fish appeared to be largely unharmed by passage through the various arc intake structures and did not exhibit extensive scale loss or bruising.

DISCUSSION

Although high variability of replicate samples limited tests of statistical significance, the efficiency of capture of yellow

perch in tests conducted at maximum current velocity was approximately twice that obtained in tests conducted at reduced current velocity. This suggests that capture efficiency increases with velocity of current in the intake structure. If the test intake structures are to be used in the field in conjunction with a Hidrostal pump, however, the trend for fish mortality and injury to increase with pump speed (OHRDR 82-295-K) must also be taken into account. Accordingly, the speed selected will represent a compromise between capture efficiency and mortality at specific test speeds.

With filtered mercury vapor lighting, capture efficiency of gizzard shad increased with length of intake structure, while without filtered mercury vapor lighting capture efficiency did not vary consistently among intake structures. These results indicate that the presence of filtered mercury vapor lighting is important in directing or orienting the response of the shad to the intake structure. The finding that when filtered mercury lighting was employed, higher capture efficiencies were obtained with the longer arcs indicates that either the more gradual increase in current or the greater degree of structure realized with these arcs is preferable to that obtained with shorter arcs. Accordingly, the intake structure of a Hidrostal pump fish return system should be designed with as gradual a change in current velocity as is feasible.

Filtered mercury vapor lighting did not consistently affect capture efficiency of either perch or gizzard shad. This finding seems contrary to previous observations that filtered mercury vapor lighting appeared effective in concentrating fish in both lab and field trials (OHRDR 82-288-K; OHRDR 83-250-K) and that filtered mercury vapor lighting increased the efficiency of capture smelt and alewife a Hidrostal pump system (OHRDR 83-142-K; OHRDR C83-54-K). This discrepancy may in part be explained by the observation that the test fish were positively rheotactic and frequently maintained position at the upstream end of the test tank. In this position it is likely that the fish were unable to perceive the filtered mercury vapor light and thus were not susceptible to its influence. If this problem were to occur in field operations, a number of alternative solutions are suggested. The first of these would involve the sequential use of a series of filtered mercury vapor lights to lead fish to the intake structure. Field trials of the use of sequential mercury vapor lighting have met with some success (OHRDR 83-250-K) and this technique would appear to have considerable potential. Alternatively, devices such as strobe lights or pneumatic poppers which induce a startle response in fish could be used intermittently to drive fish into the intake structure. Both strobe lighting and pneumatic poppers have shown some promise in

diverting fish in field trials (OHRDR 81-61-K; ESEERCO Report EP1 83-12).

Much of the variability in capture efficiency of both perch and gizzard shad appeared to be associated with the tendency of both fish, particularly gizzard shad, to swim in schools. Capture thus became an all or nothing response with either many or no fish caught in a given trial. Schooling behavior of freshwater fish is often reduced at night (Emery 1973) and it was hoped that contrasts between day and night tests would clarify the effects of schooling on capture efficiency. Unfortunately, however, capture efficiency with no arc was low in all trials and the effects of day and night behavior on capture efficiency could not be differentiated.

SUMMARY

1) With filtered mercury vapor lighting, the efficiency of capture of gizzard shad was higher for longer intake structures in which current velocity increased more gradually. Without mercury vapor lighting, no consistent pattern was apparent between capture efficiency and intake structure.

2) Capture efficiency of yellow perch appeared to increase at higher current velocities, however, the large variability among replicate samples limited tests of statistical significance.

ACKNOWLEDGEMENTS

The technical assistance of H. Kowalyk, B. Sim and J. Battrick is gratefully acknowledged.

Approved:

D. Harrison
Manager
Chemical Research Dept

Submitted:

D.W. Rodgers
Biologist
Biological Research Section

DWR:dwr/clg

REFERENCES

Emery, A.R. 1973. Preliminary comparisons of day and night habits of freshwater fish in Ontario lakes. J.Fish. Res. Board Can. 30: 761-774.

Empire State Electric Energy Research Corporation Report EP-1 83-12. Alternative fish protection techniques: pneumatic poppers and rope nets. 107p.

Ontario Hydro Research Division Report No 78-516-K. Response of fish to light. P.H. Patrick, December 29, 1978.

Ontario Hydro Research Division Report No 79-362-K. Effects of fish size and temperature on sustained swimming speeds of Great Lakes fish. J.S. Griffiths, August 24, 1979.

Ontario Hydro Research Division Report No 81-61-K. American eel response to white strobe light - R.H. Saunders 1980. R.W. Sheehan and B. Sim, October 14, 1981.

Ontario Hydro Research Division Report No 82-288-K. Responses of alewife and smelt to filtered mercury vapor light. P.H. Patrick, August 31, 1982.

Ontario Hydro Research Division Report No 82-295-K. Effectiveness of a Hidrostal pump and transport system in the live transfer of fish. P.H. Patrick, August 31, 1982.

Ontario Hydro Research Division Report No 83-142-K. Methods of attracting fish to a Hidrostal pump. D.W. Rodgers, April 11, 1983.

Ontario Hydro Research Division Report No 83-250-K. Effectiveness of filtered mercury vapor lights in sequence to lead fish in a forebay situation. G.T. Haymes, August 10, 1983.

Ontario Hydro Research Division Report No C83-54-K. Further tests of methods of attracting fish to a Hidrostal pump. D.W. Rodgers, August 24, 1983.

Otto R.G. and J. O'Hara Rice. 1974. Swimming speeds of yellow perch (Perca flavescens) following an abrupt change in environmental temperature. J. Fish. Res. Board Can. 31: 1731-1734.

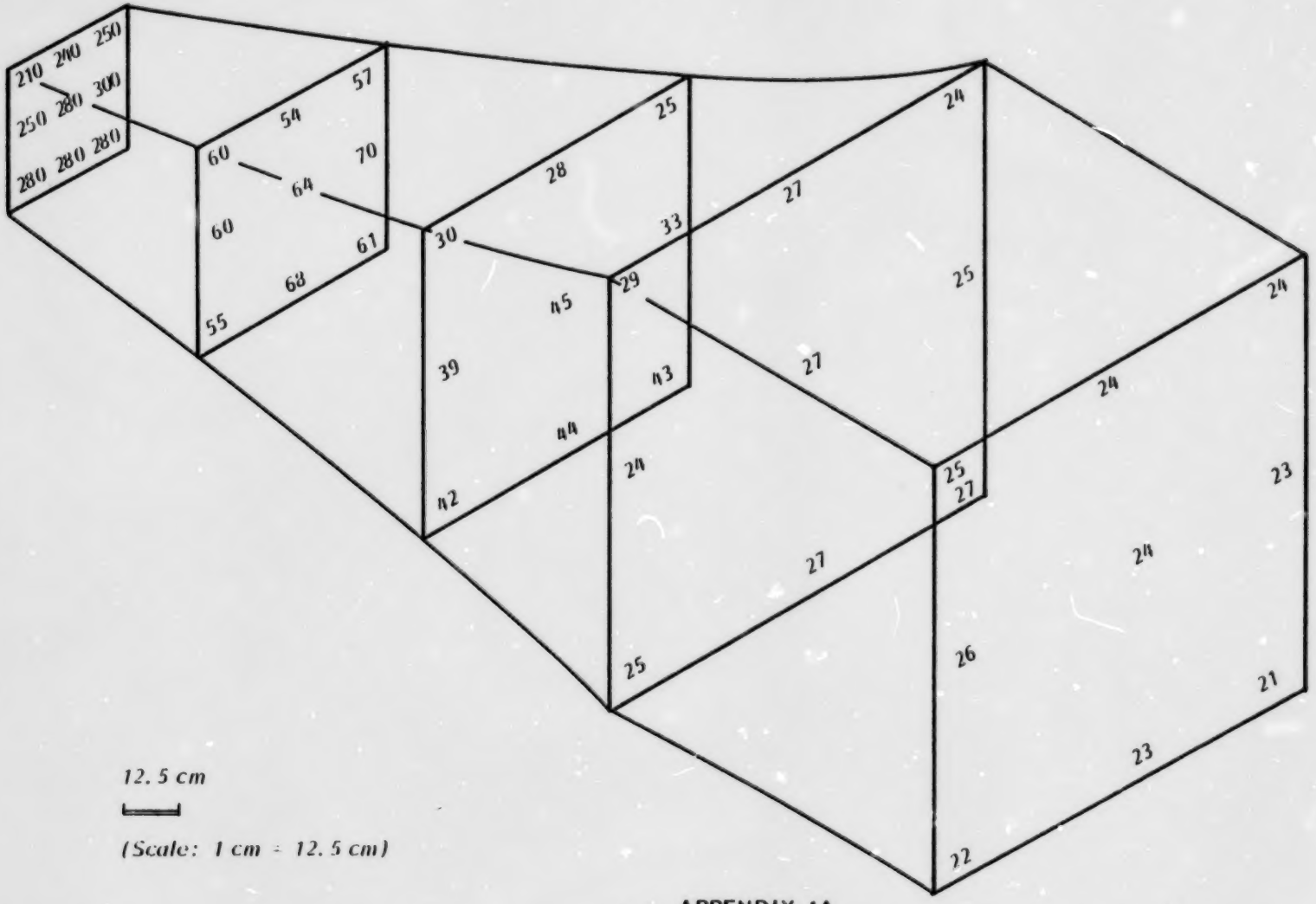
APPENDIX 1

Current distribution within tanks and 2, 3, and 4 m arcs.

a) 2 m arc

b) 3 m arc

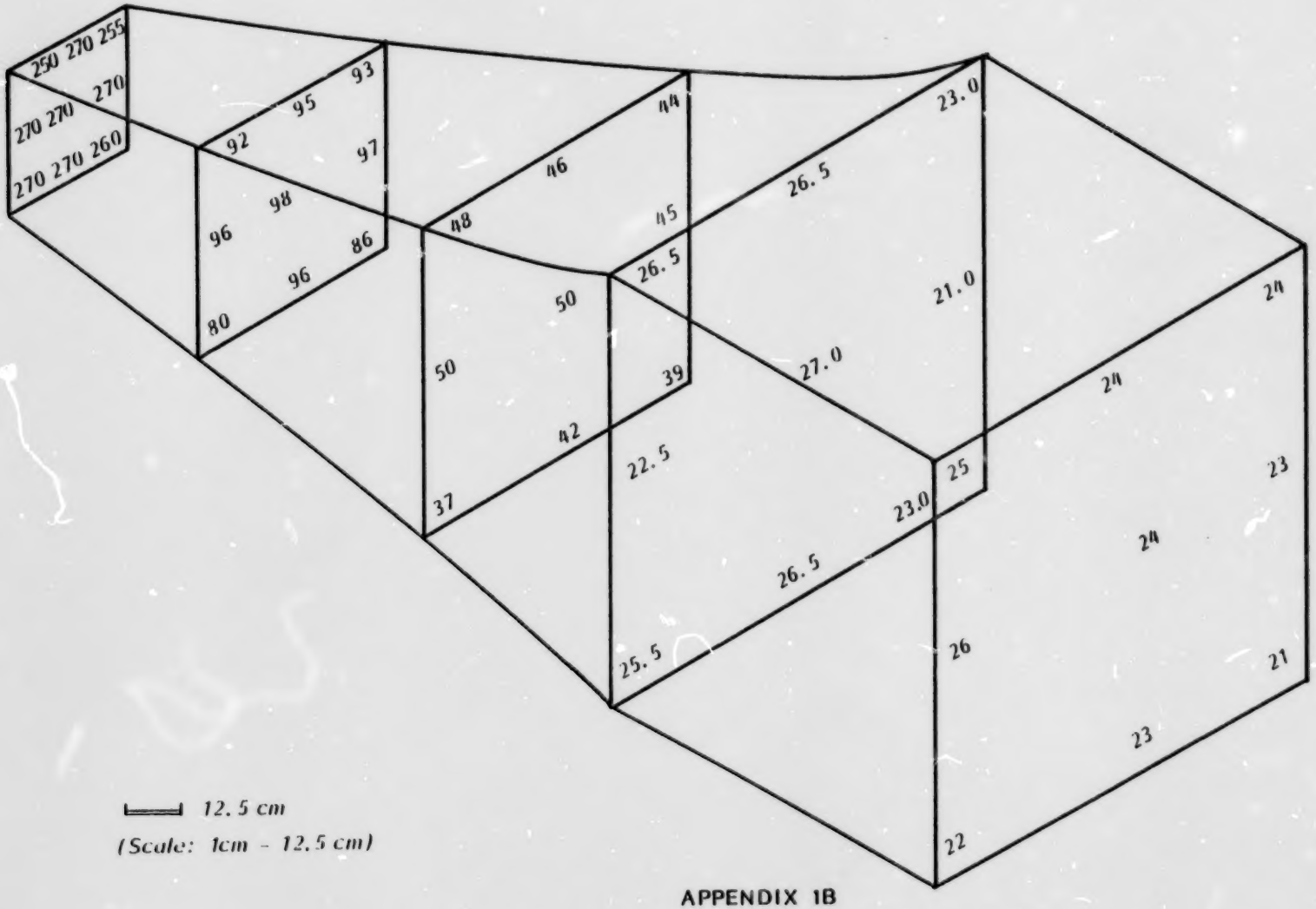
c) 4 m arc



APPENDIX 1A

CURRENT DISTRIBUTION - 2 m ARC
(VELOCITY IN cm/s)

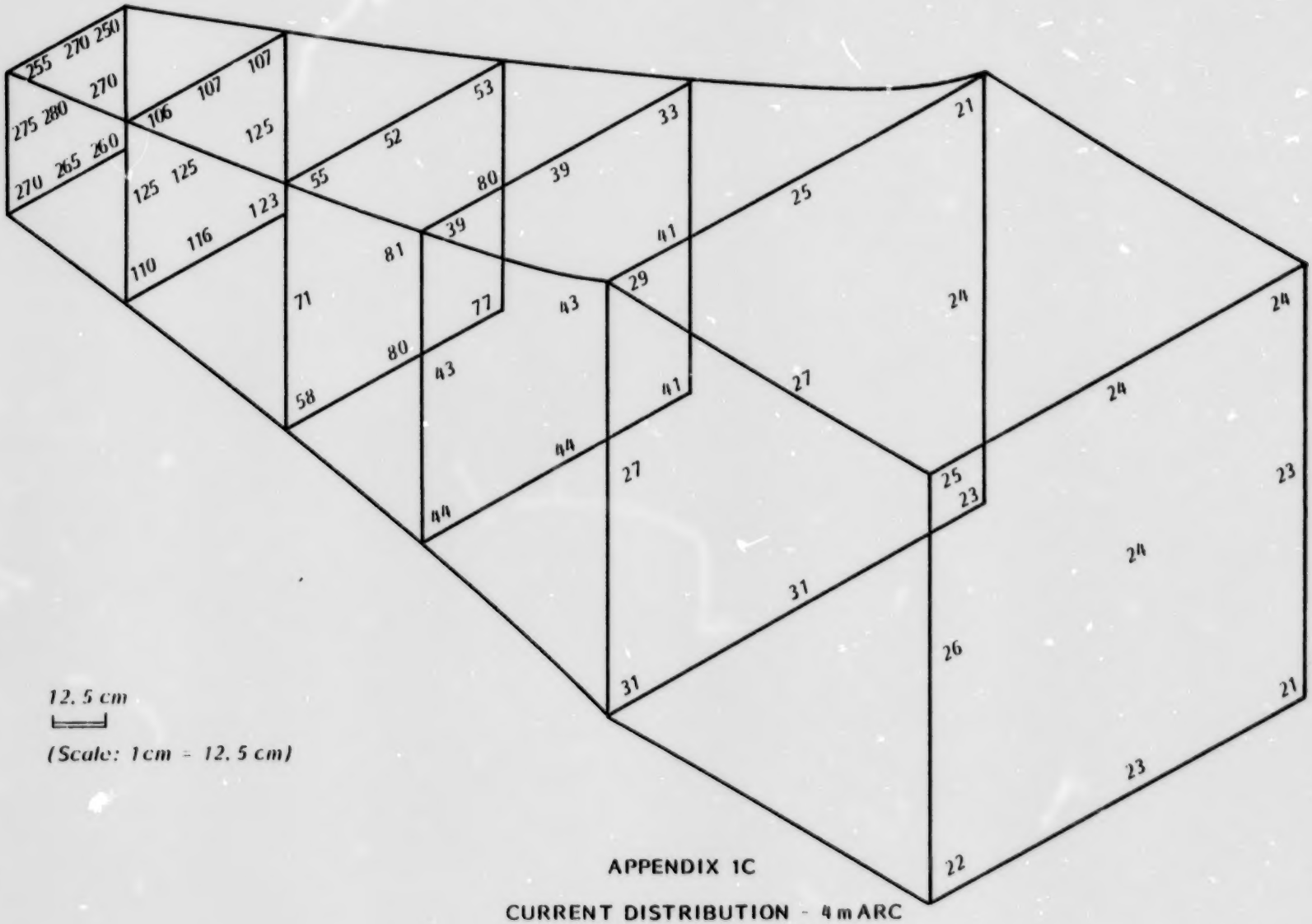
164684 RD



APPENDIX 1B

CURRENT DISTRIBUTION - 3 m ARC
(VELOCITY IN cm/s)

164685 RD



12.5 cm

(Scale: 1 cm = 12.5 cm)

APPENDIX 1C

CURRENT DISTRIBUTION - 4 m ARC
(VELOCITY IN cm/s)

164686 R.D

APPENDIX 2

Number of yellow perch captured in individual trials (Number of fish passing through intake, 25 fish/test)

	Mercury vapor lamp on	Mercury vapor lamp off
Maximum current velocity	23, 1, 6	24, 11, 5, 4
Reduced current velocity	15, 0, 0	6, 2, 0

APPENDIX 3

Number of gizzard shad captured in individual trials (Capture is the number of fish passing through the intake structure, 25 fish/test; Entry is the total number of fish entering the intake structure and includes capture and escapes)

	Mercury vapor lamp on		Mercury vapor lamp off	
	Entry(#)	Capture(%)	Entry(#)	Capture(%)
No arc (Day)	-------	4,1,0,1	-------	2,13,5,8
No arc (Night)	-------	3,0,0,12	-------	0,6,5,13
2 m arc	27,8,25,39	1,4,8,20	7,12,4,29	2,2,0,6
3 m arc	31,18,17,16	9,7,19,12	25,44,43,36	14,23,20,11
4 m arc	57,57,31,46	19,14,9,16	17,25	6,5